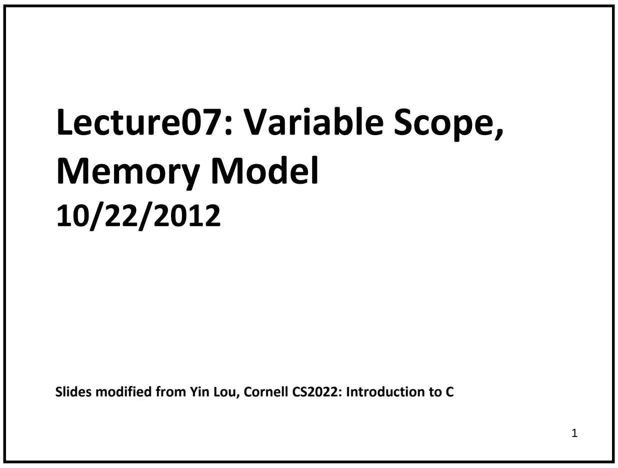

Lecture07: Variable Scope, Memory Model
10/22/2012

Slides modified from Yin Lou, Cornell CS2022: Introduction to C

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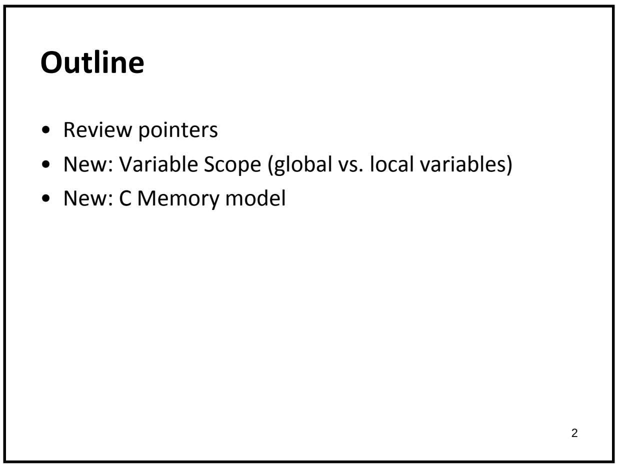

Outline

- Review pointers
- New: Variable Scope (global vs. local variables)
- New: C Memory model

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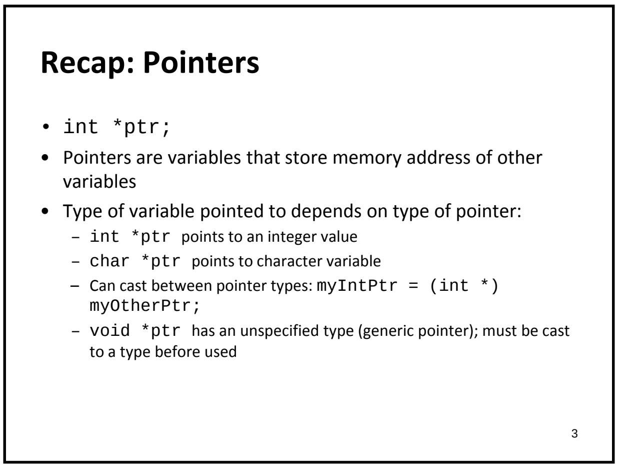

Recap: Pointers

- `int *ptr;`
- Pointers are variables that store memory address of other variables
- Type of variable pointed to depends on type of pointer:
  - `int *ptr` points to an integer value
  - `char *ptr` points to character variable
  - Can cast between pointer types: `myIntPtr = (int *) myOtherPtr;`
  - `void *ptr` has an unspecified type (generic pointer); must be cast to a type before used

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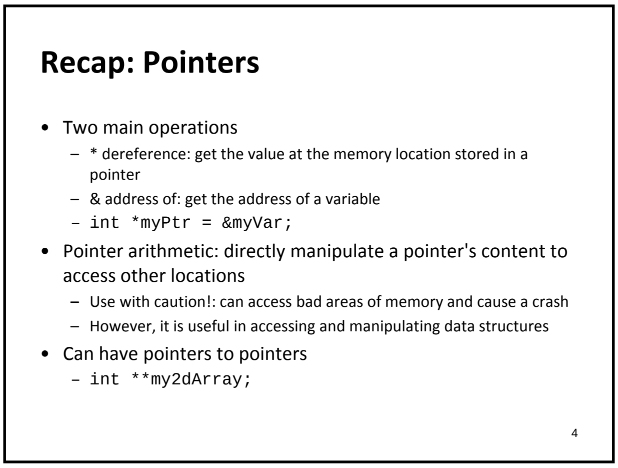

Recap: Pointers

- Two main operations
  - * dereference: get the value at the memory location stored in a pointer
  - & address of: get the address of a variable
  - `int *myPtr = &myVar;`
- Pointer arithmetic: directly manipulate a pointer's content to access other locations
  - Use with caution!: can access bad areas of memory and cause a crash
  - However, it is useful in accessing and manipulating data structures
- Can have pointers to pointers
  - `int **my2dArray;`

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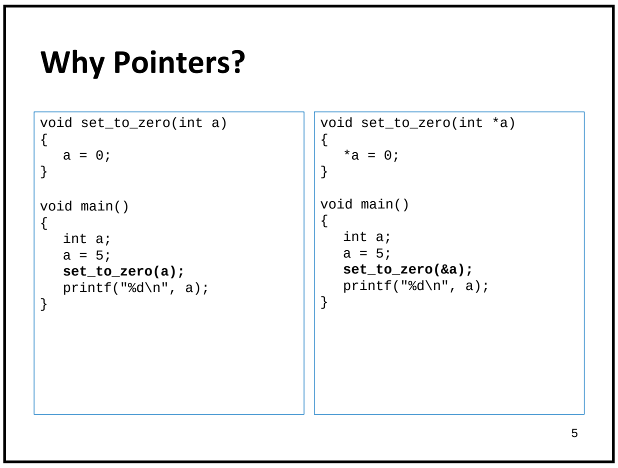

Why Pointers?

```
void set_to_zero(int a)
{
   a = 0;
}

void main()
{
   int a;
   a = 5;
   set_to_zero(a);
   printf("%d\n", a);
}
```

```
void set_to_zero(int *a)
{
   *a = 0;
}

void main()
{
   int a;
   a = 5;
   set_to_zero(&a);
   printf("%d\n", a);
}
```

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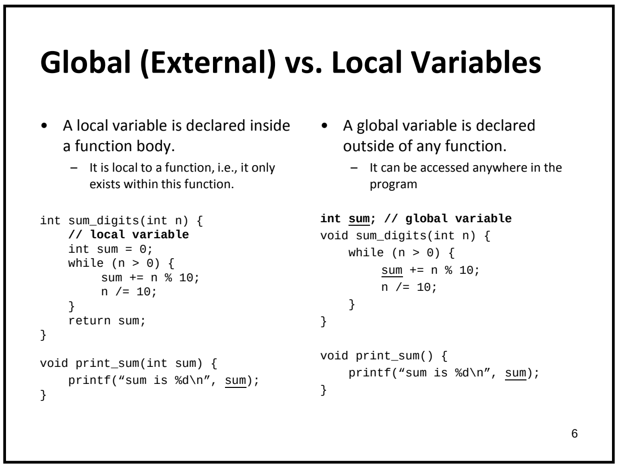

Global (External) vs. Local Variables

- A local variable is declared inside a function body.
  - It is local to a function, i.e., it only exists within this function.

```
int sum_digits(int n) {
    // local variable
    int sum = 0;
    while (n > 0) {
        sum += n % 10;
        n /= 10;
    }
    return sum;
}

void print_sum(int sum) {
    printf(“sum is %d\n”, sum);
}
```

- A global variable is declared outside of any function.
  - It can be accessed anywhere in the program

```
int sum; // global variable
void sum_digits(int n) {
    while (n > 0) {
        sum += n % 10;
        n /= 10;
    }
}

void print_sum() {
    printf(“sum is %d\n”, sum);
}
```

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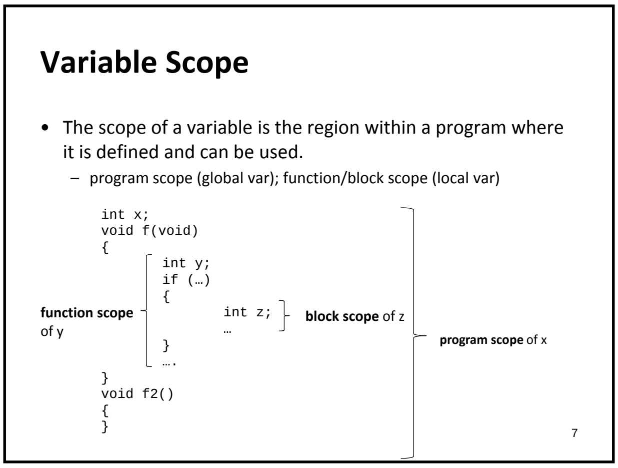


Variable Scope

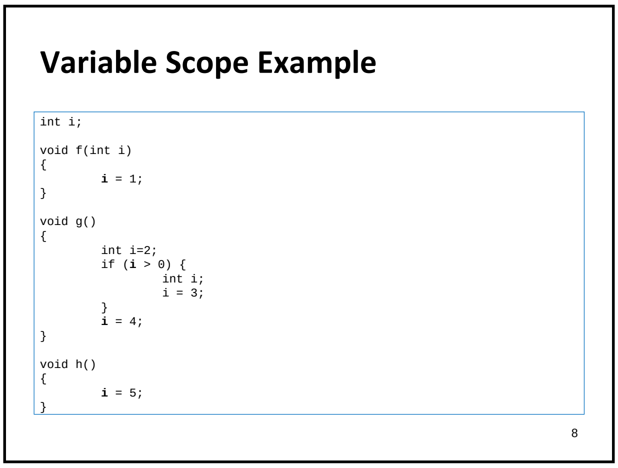
- The scope of a variable is the region within a program where it is defined and can be used.
  - program scope (global var); function/block scope (local var)

```
int x;
void f(void)
{
        int y;
        if (…)
        {
                int z;
                …
        }
        ….
}
void f2()
{
}
```

function scope of y

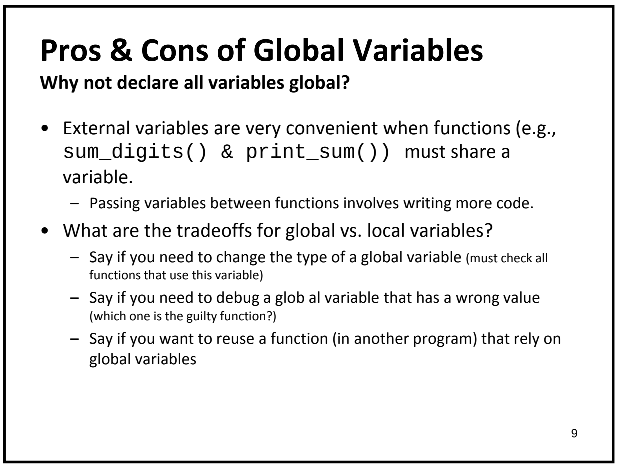
block scope of z

program scope of x



Variable Scope Example

```
int i;

void f(int i)
{
        i = 1;
}

void g()
{
        int i=2;
        if (i > 0) {
                int i;
                i = 3;
        }
        i = 4;
}

void h()
{
        i = 5;
}
```



Pros & Cons of Global Variables

Why not declare all variables global?

- External variables are very convenient when functions (e.g., `sum_digits() & print_sum())` must share a variable.
  - Passing variables between functions involves writing more code.
- What are the tradeoffs for global vs. local variables?
  - Say if you need to change the type of a global variable (must check all functions that use this variable)
  - Say if you need to debug a glob al variable that has a wrong value (which one is the guilty function?)
  - Say if you want to reuse a function (in another program) that rely on global variables

In-Class Exercise 6-1

- Write a simple game-playing program. The program generates a random number between 1 and 100, which the user attempts to guess in as few tries as possible. Your program should have the following input & output:

```
Guess the secret number between 1 and 100
Enter guess: 55
Too low, try again.
Enter guess: 65
Too high, try again.
Enter guess: 61
You won in 4 guesses!
Play again? (Y/N) Y

Guess the secret between 1 and 100
Enter guess: 31
```

More on Exercise 6-1

- You program should have the following global variable and functions.

```
#include <stdio.h>
#include <time.h>

int secret_num; // global var to store the secret num
void init_num_generator()
{
        srand(time);   // initialize the seed of random number 
generator
}
// select a new secret number
void new_secret_num()
{
        secret_num = rand() % 100; // a random number 0-99
}

// continuously read user guesses and tell too low/high/correct
void read_guesses();
```

Static Local Variables

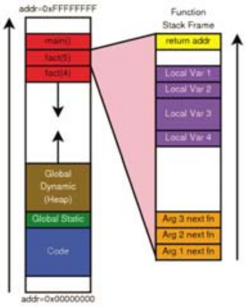
A permanent storage inside a function so its value is retained throughout the program execution (vs. local variable, its storage is gone at the end of the function)

```
/* Program which sums integers, using static variables */
#include <stdio.h>
void sumIt(void);

int main() {
        int i =0;
        printf("Enter 5 numbers to be summed\n");
        for(i = 0; i<5; ++i)
                sumIt();
        printf("Program completed\n");
        getchar();
        return 0;
}

void sumIt(void) {
        static int sum = 0;
        int num;
        printf("\nEnter a number: ");
        scanf("%d", &num);
        sum+=num;
        printf("The current sum is: %d",sum);
}
```

C Memory Model

- Program code
- Function variables
  - Arguments
  - Local variables
  - Return location
- Global Variables
  - Statically allocated
  - Dynamically allocated

```
int fact (int n)
{
  return(n*fact(n-1));
}
```



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The Stack

- Stores
  - Function local variables
  - Temporary variables
  - Arguments for next function call
  - Where to return when function ends

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The Stack

- Managed by compiler
  - One stack frame each time function called
  - Created when function called
  - Stacked on top (under) one another
  - Destroyed at function exit

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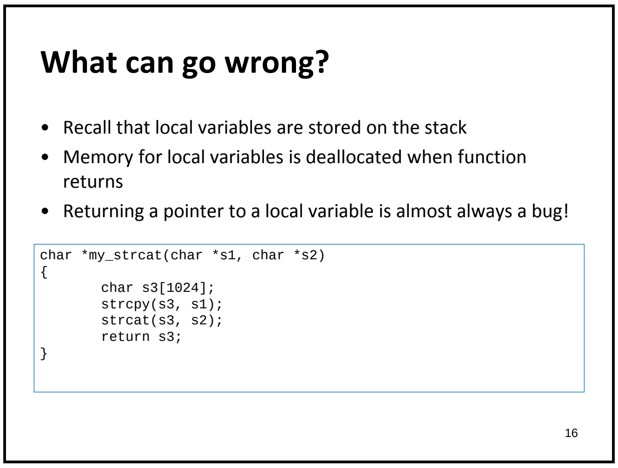
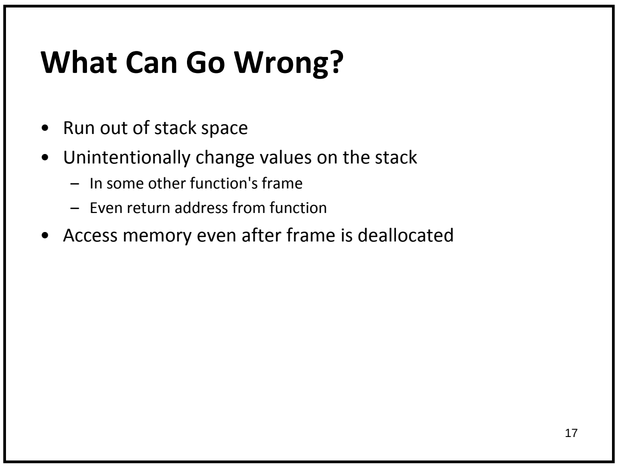


What can go wrong?

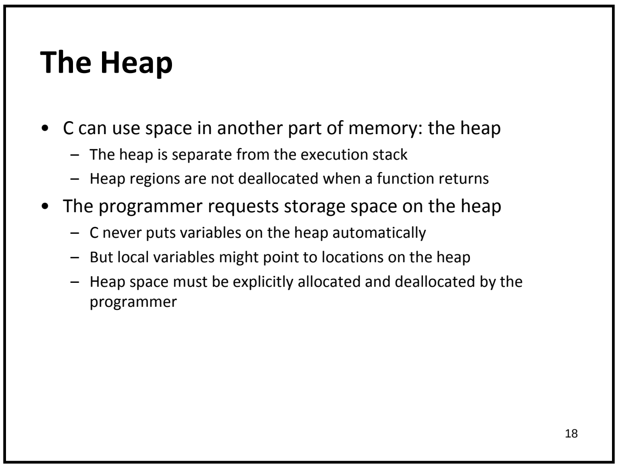
- Recall that local variables are stored on the stack
- Memory for local variables is deallocated when function returns
- Returning a pointer to a local variable is almost always a bug!

```
char *my_strcat(char *s1, char *s2)
{
       char s3[1024];
       strcpy(s3, s1);
       strcat(s3, s2);
       return s3;
}
```



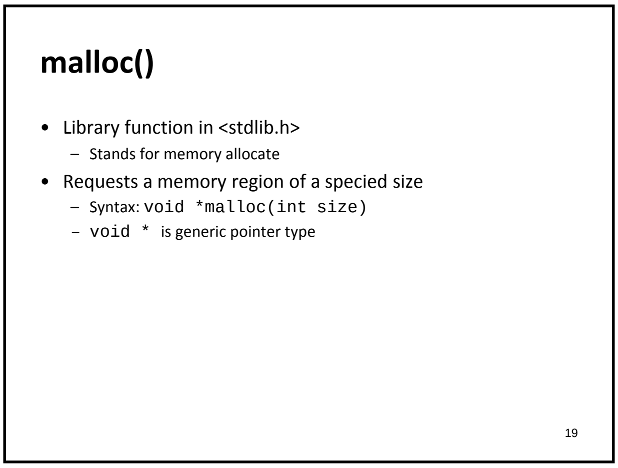
What Can Go Wrong?

- Run out of stack space
- Unintentionally change values on the stack
  - In some other function's frame
  - Even return address from function
- Access memory even after frame is deallocated



The Heap

- C can use space in another part of memory: the heap
  - The heap is separate from the execution stack
  - Heap regions are not deallocated when a function returns
- The programmer requests storage space on the heap
  - C never puts variables on the heap automatically
  - But local variables might point to locations on the heap
  - Heap space must be explicitly allocated and deallocated by the programmer



malloc()

- Library function in <stdlib.h>
  - Stands for memory allocate
- Requests a memory region of a specied size
  - Syntax: `void *malloc(int size)`
  - `void *` is generic pointer type

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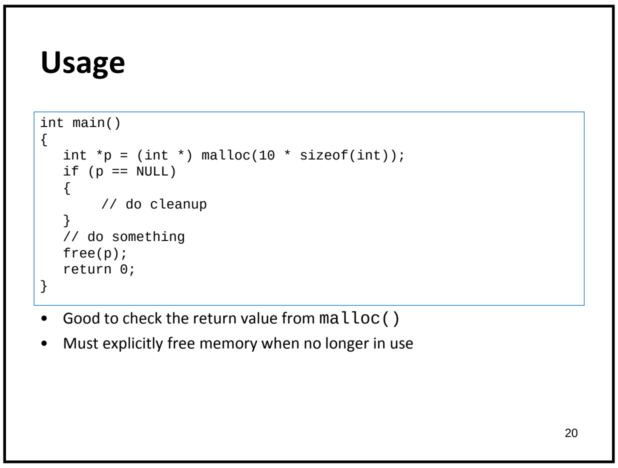

Usage

```
int main()
{
   int *p = (int *) malloc(10 * sizeof(int));
   if (p == NULL)
   {
        // do cleanup
   }
   // do something
   free(p);
   return 0;
}
```

- Good to check the return value from `malloc()`
- Must explicitly free memory when no longer in use

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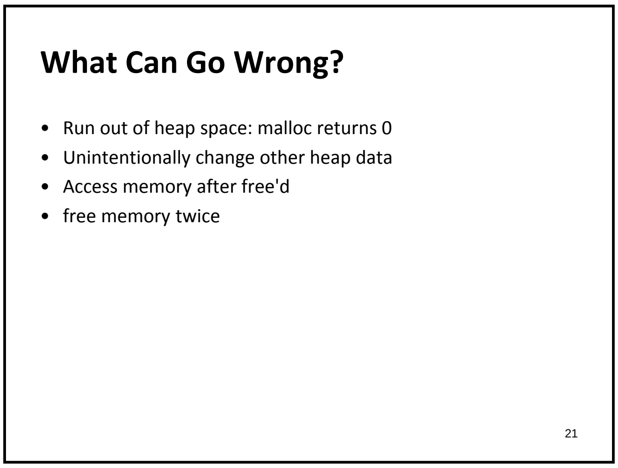

What Can Go Wrong?

- Run out of heap space: malloc returns 0
- Unintentionally change other heap data
- Access memory after free'd
- free memory twice

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Usage

```
#include <stdio.h>
#include <stdlib.h>

int main()
{
   int *p = (int *) malloc(10 * sizeof(int));
   if (p == NULL)
   {
        // do cleanup
   }
   // do something
   if (p != NULL)
   {
        free(p);
        p = NULL;
   }
   return 0;
}
```

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Multidimensional Array

- On the stack: `int a[10][20];`
- Initialization: `int a[][] = {{1, 2, 3}, {4, 5, 6}};`
- Accessing the array: `a[1][0]`
- On the heap

```
int **a = (int **) malloc(10 * sizeof(int *));
for (int i = 0; i < 10; ++i)
{
  a[i] = (int *) malloc(20 * sizeof(int));
}
```

- Don't forget to free them!

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Exercise 6-2

Write a program that (1) asks for the number of friends, (2) asks for a name, and (3) checks a series of strings to see which one matches the names of friends. Please use

- Use `malloc()` to create this multi-dimensional array of friends' names. You can assume that the friends' names are less than 10 characters.
- Use `<string.h>` library
- Use `scanf("%s", ..)` to read a name separated by one or more whitespaces

```
Input the number of your friends: 4
John Polly Peter Jane
Input a name: Jane
Jane is friend #4
Input a name: Mary
Mary is not a friend
```

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